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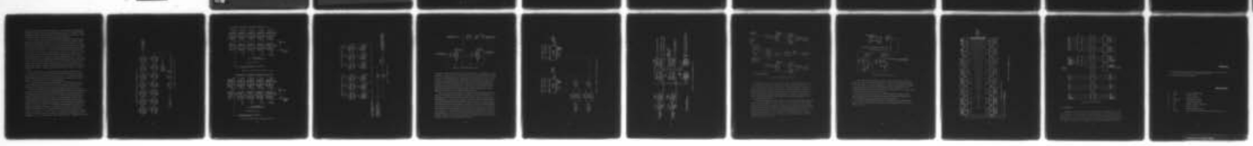

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A Computer Controlled Tracking System: Interface Circuits Design

MICHAEL J. SOWA

15 February 1977

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FOR THE COMMANDER

John Howard

Chief Scientist

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In this report the design and application of the circuits used to interface a Lockheed SUE mini-computer with a Canoga Antenna Tracking System are described. Basic material on the theory and application of the antenna tracking system is also presented.

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Contents

Illustrations

Illustrations

Tables

A Computer Controlled Tracking System: Interface Circuits Design

1. INTRODUCTION

The objective of this report is to present a detailed explanation covering the design and application of the circuits used to interface a Lockheed SUE mini-computer with a Canoga Antenna Tracking System. The techniques and instrumentation systems developed will provide a capability for computer-controlling a ground-based telemetry tracking antenna. This technique will significantly improve the research probe tracking systems used to support the AFGL conducted environmental research programs as well as available missile tracking technology. The ground based system will be utilized broadly by the AFSC 6.2 Environment Programs that are conducted at remote sites such as Natal, Brazil, and Poker Flat, Alaska.

2. BACKGROUND MATERIAL

The existing ground-based telemetry tracking system presently in use at the AFGL Research Probe Instrumentation Branch consists of the following major components:

(a) Antenna Feed Assembly,

(b) Monoscan Converter,

(Received for publication 14 February 1977)

(c) Preamplifier,

(d) Track Receiver,

(e) Servo Control System.

When the system is in operation, RF signals, whose frequencies are within the operating band of the antenna and striking the ten dipoles that comprise the antenna array, induce signal voltages into the dipoles. These induced signal voltages have phase relationships that are a function of the incident angle of the antenna with respect to the RF source.

The signal voltages induced into the dipoles are coupled into the comparison and polarization-selection components within the feed assembly where they are electrically combined and switched so that a right-hand circular or vertically polarized RF wavefront striking the antenna dipole will produce two pointing-error signals and one sum signal from the feed assembly. The three RF signal outputs of the feed are then coupled to the monoscan converter. There, the two error signals are fed via electronic switching and phase-shift networks to an algebraic adder component where they are vectorially added to the sum signal to produce a single phase and amplitude modulated RF (multiplex) signal.

The multiplex signal is then routed to the preamplifiers where the signal strength is increased prior to feeding it to the receiver. At the receiver the signal is converted down and demodulated producing limited and unlimited IF in addition to video output signals that are usable by other equipment for extracting data that may be contained in the original transmitted sum signal. The phase and amplitude modulated video signal contains the pointing-error data that is used by the servo subsystem to drive the antenna to track the source of the received signal.

The tracking antenna system is capable of operating in any of three main modes and in two submodes. The three main operating modes are as follows:

(a) Manual Mode,

(b) Slave Mode,

(c) Autotrack Mode.

The two submodes are the spiral scan and joystick manual override. A description of each mode follows:

(a) Manual Mode. In the manual or handwheel mode of operation, the handwheel synchro transmitters (which are operator positioned by the handwheels through clutch mechanisms and reduction ratio gearboxes) are the source of the error signals to the positioning servos.

(b) Slave Mode. In the slave mode of operation, the antenna positioning servo loops derive error signal inputs from one of three remote synchro units which are selected by means of switches. Remotes 1 and 2 are tracking sources such as another tracking system and Remote 3 is the optical tracking unit supplied with the equipment.

(c) Spiral Scan Mode. When the spiral scan mode of operation is selected the scan generator circuits are utilized to generate the search error signals. A spiral pattern of approximately 20 deg from the manual or slave commanded position with a corresponding radius of approximately 10 deg results. Operation in this mode is only possible wher each axis is also in the manual or slave mode.

(d) Joystick Override Mode. When the insert button on the joystick is pressed, dc error signals are generated, the amplitudes of which are dependent upon the amount of pressure applied to the joystick in the axis of travel desired. This sub-mode is only possible in the manual or slave modes of operation.

(e) Autotrack Mode. In the autotrack mode of operation, control of each of the antenna axes is accomplished using demultiplexed error signals which are produced by the receiver when pointing errors exist.

The circuits described in this document provide for the capability of a fourth main mode of operation called the computer mode. Whenever this mode is selected by the operator, the tracking system will derive trajectory data from the mini-computer rather than from the RF source and will continue to track in this mode until another is selected. Error signals are created by taking the difference between the actual antenna position and the predicted antenna position at a given instant in time and feeding this error voltage to the servo system. This added capability will greatly increase the flexibility of the tracking system. Reacquisition of lost vehicles and/or best guess acquisition of vehicles whose signals have not previously been acquired (for example, satellite passes) will now become feasible. Previous methods would only allow random search patterns that were very seldom successful.

3. DESIGN AND APPLICATIONS

Tracking information from the computer in a BCD format is sequentially placed on the computer's 16 data-output lines and is then strobed to a series of 4-bit shift registers (buffer registers). The specific format utilized is as follows:

Azimuth — 5 BCD characters (0 to 365.99 deg),

Elevation — 4 BCD characters (0 to 99.99 deg),

Time — 7 BCD characters (0 to 166.667 min).

The strobing of data into the proper registers is accomplished using the circuit of Figure 1. With the computer read/write line in the write mode the strobe pulse is gated to the fourth address line of the binary to octal decoder (8250). With the correct address on the other three input lines (Table 1), the output line corresponding to the proper registers is activated. Once all of the data has been sequenced to the proper registers, it is then strobed simultaneously to a second series of 4-bit shift registers (interface registers). This action clears the buffer registers for the next set of data values to be sequenced in. This circuit is illustrated in Figure 2.

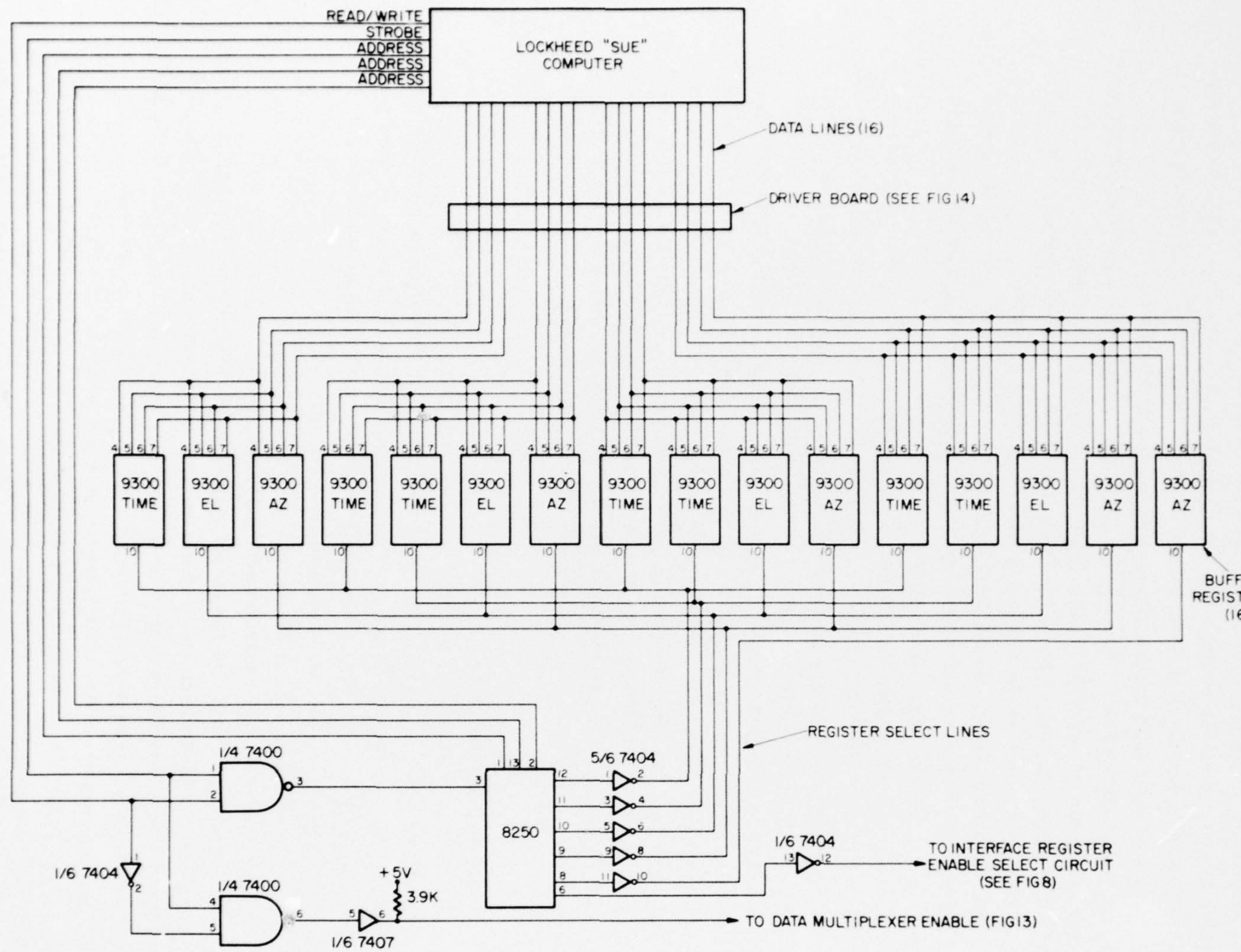

Figure 1. Register Select Circuit

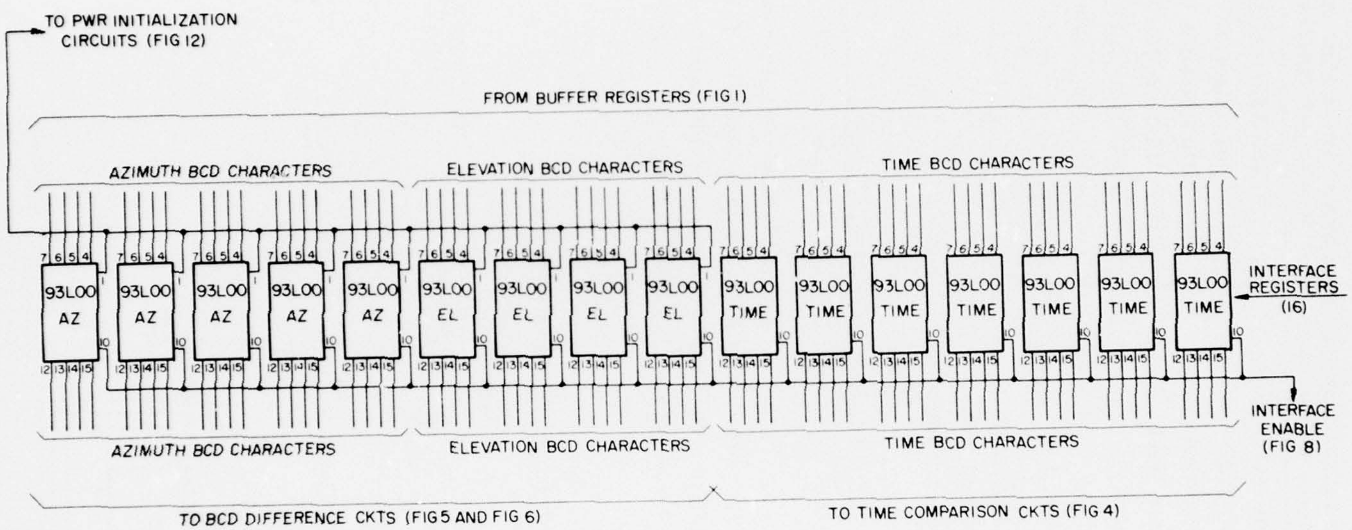

Figure 2. Interface Register Circuit

Table 1. Address Line Definitions

Read Mode Address Definitions	Write Mode Address Definitions
000 Azimuth (MA)	000 Azimuth (MP)
001 Azimuth (LA)	001 Azimuth (LP)
010 Elevation (MA)	010 Elevation (P)
011 Elevation (LA)	011 Time (MP)
100 Time (MA)	100 Time (LP)
101 Time (LA)	111 Pre-Flight Load
110 Range (MA)	
111 Range (LA)	

M Most Significant Bits
L Least Significant Bits
A Actual
P Predicted

The internal circuitry of the Lockheed SUE mini-computer requires that a pulse be returned to the computer each time data is strobed. This pulse must occur within 2 μsec of the strobe pulse in order to verify data reception. The circuit utilized to provide this function is shown in Figure 3. In addition to applying

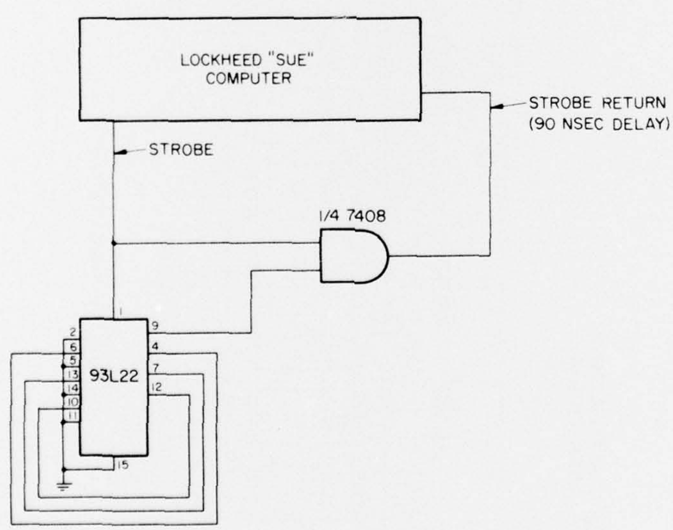

Figure 3. Strobe Return Pulse Circuit

the strobe pulse to the binary to octal decoder, it is also applied to a wired delay of 80 nsec (93L22) and also to an AND gate (25-nsec delay). The output of the AND gate produces a pulse approximately 95 nsec after the strobe occurs which is sufficient time to allow the data to be loaded into the buffer registers.

Once the data has been strobed into the interface registers it begins to be processed. The time characters are sent to a comparator network (Figure 4) where they are compared with the output of an accurate time code generator to a resolution of 1 msec. At the same time, the predicted azimuth and elevation information is compared and subtracted from the actual azimuth and elevation producing a BCD difference (see Figures 5 and 6). This actual azimuth and elevation information is derived from the tracker's existing encoders. When a time comparison occurs, the comparator network generates a pulse which latches the BCD azimuth and elevation difference at that moment into the LED display (MDA 6101). This same pulse is also applied to a monostable multivibrator (9602) from which, approximately 1 μsec later, an output pulse latches the data from the buffer registers into the interface registers and, approximately 1 μsec later still, an interrupt pulse is applied to the computer causing it to begin sequencing a new set of data values out to the buffer registers. The operation of these circuits is illustrated in Figures 7 and 8.

Since the latching and interrupt pulses are automatically generated at each time comparison, the system can operate on variable time increments limited only by the minimum resolution of the counters (1 msec). This scheme allows for frequent updates of fast moving vehicles (for example, rockets) and non-frequent updates of slower ones (for example, satellite passes).

The visual LED display permits the operator to view how close to the predicted flight path the trajectory actually is, thereby allowing the option of either switching to the computer mode or to the scan mode in the event of an LOS.

The three least significant BCD digits (representing 0 to 9.99 deg) of the azimuth and elevation differences are continually applied to digital to analog converters (CY-2638) whose outputs drive the azimuth and elevation servos that control the position of the tracking antenna (Figure 9). The output of each D/A converter is fed to the OP-AMP circuit shown in Figure 10, which produces a bipolar output of approximately 10 V magnitude. Depending upon the position of relay R-2 for elevation or R-3 for azimuth, either a positive or negative voltage is generated and applied to the summing junction of integrated circuit A1 located on the tracker's existing demodulator circuit board. The positions of relays R-2 and R-3 are controlled by the output of the +/- sign generator, which is a part of the BCD subtractor circuit shown in Figures 5 and 6. The result is a voltage of the correct polarity to drive the antenna in a direction which reduces the azimuth and elevation differences. The D/A converter will produce approximately 5 V output for 10 deg error.

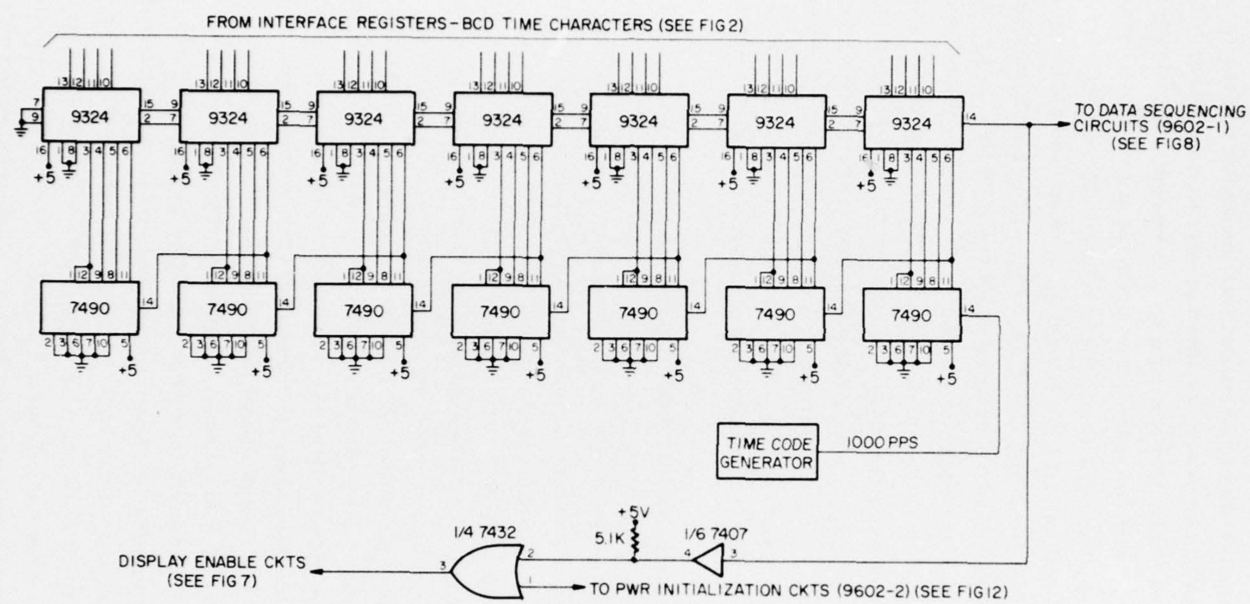

Figure 4. Time Comparison Circuits

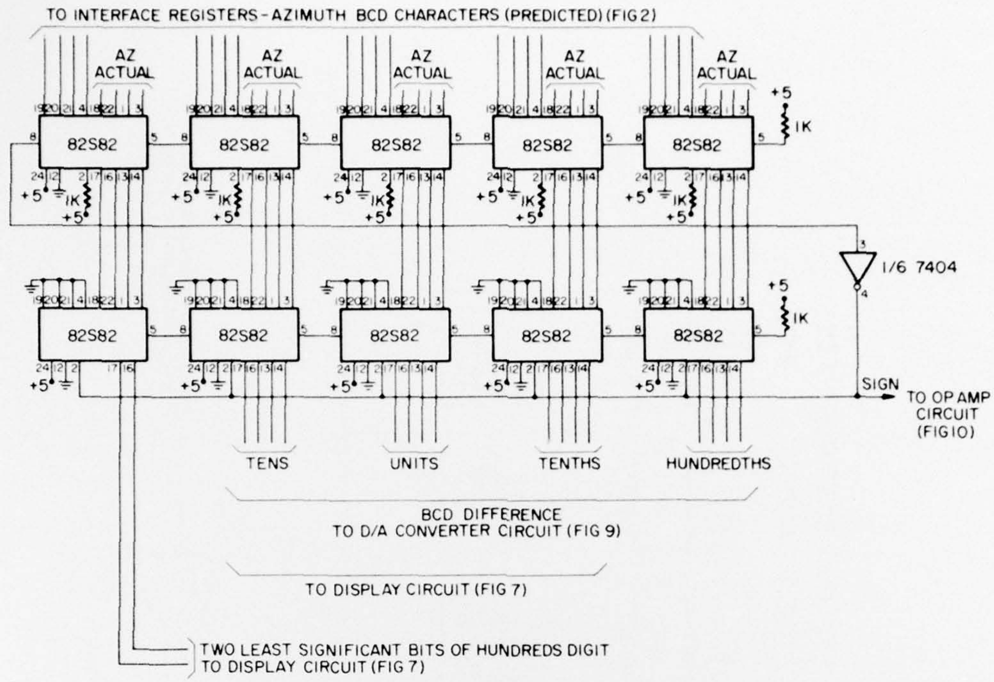

Figure 5. Azimuth BCD Difference Circuit

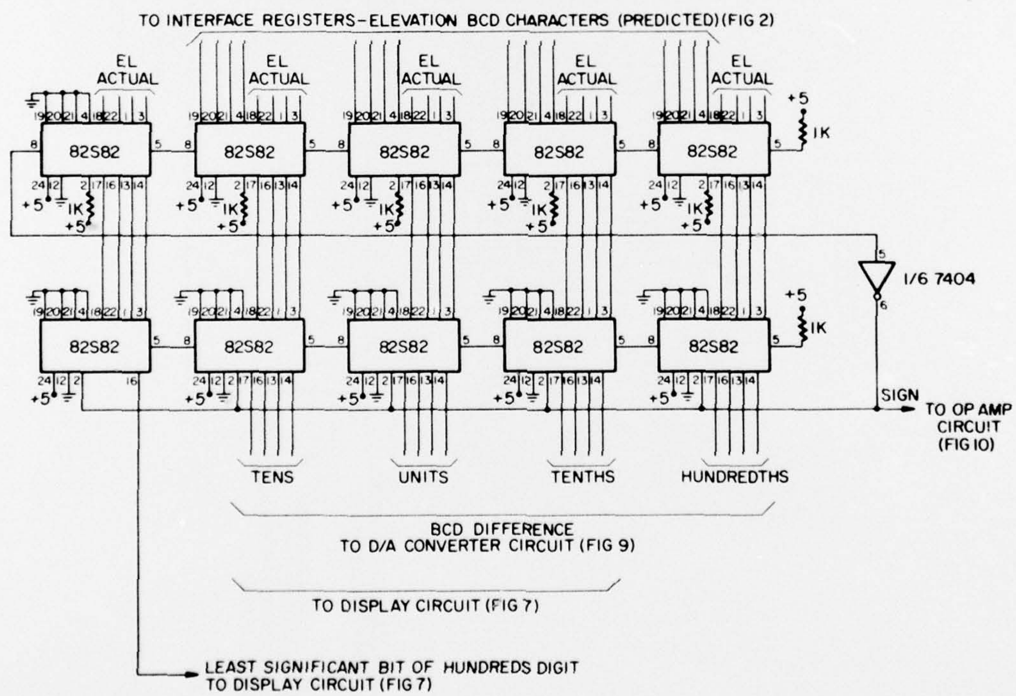

Figure 6. Elevation BCD Difference Circuit

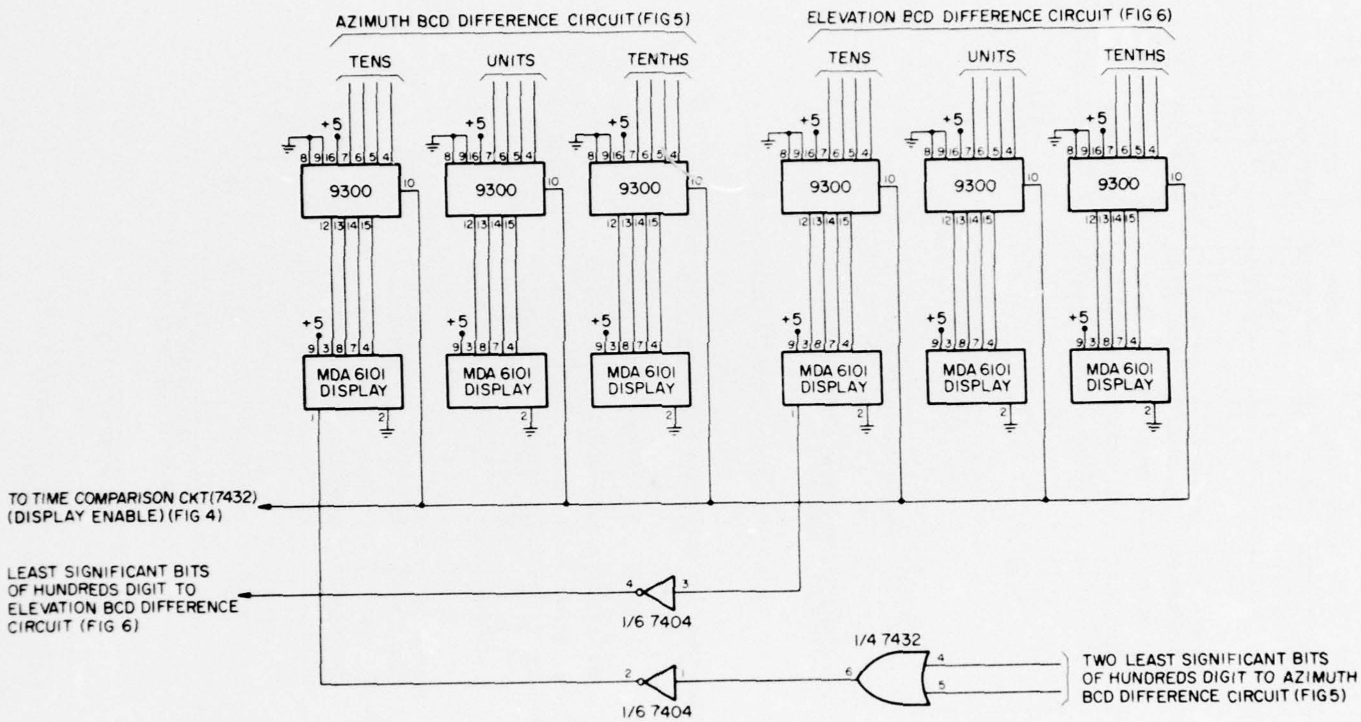

Figure 7. Display Circuit

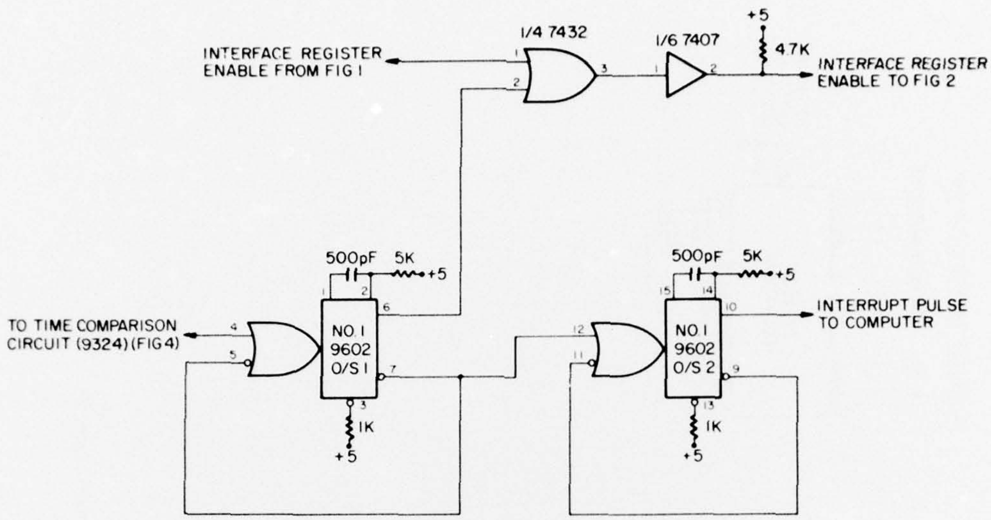

Figure 8. Data Sequencing Circuit

Sensitivity is controlled by adjusting the 10K potentiometer at the output of the D/A converter. The tens digit from the BCD azimuth and elevation difference is applied to a series of OR gates (Figure 9) which control the overrange bit on the D/A converters. Thus, whenever there is a difference of greater than 9.99 deg the overrange bit will be activated and the output voltage will increase accordingly to a maximum of 10 V at 19.99 deg error. A similar scheme is utilized in the LED display which allows the decimal point to the left of the most significant digit to light up should there be an overrange condition existing (greater than 99.9 deg difference) in either azimuth or elevation (see Figure 7).

The tracking system is placed into the computer mode by depressing the computer switch located on the front panel. In order to avoid the complexities of redesigning some of the existing logic associated with the tracker, a scheme was utilized whereby a closure of the computer mode switch would essentially energize the master auto switch thereby activating all bus and submode relays and lights associated with master auto. However, the input of the error signals provided by the tracking receiver is disconnected from the summing amp via the summing amp input relay and the error signals derived from the D/A converters are connected (see Figure 10). Thus the position of the antenna is now under control of the computer predictions. In order to provide clean signals at the input of the dual D flip flop that controls the summing amp input relay, a debounce circuit is utilized. The operation of this circuit is illustrated in Figure 11.

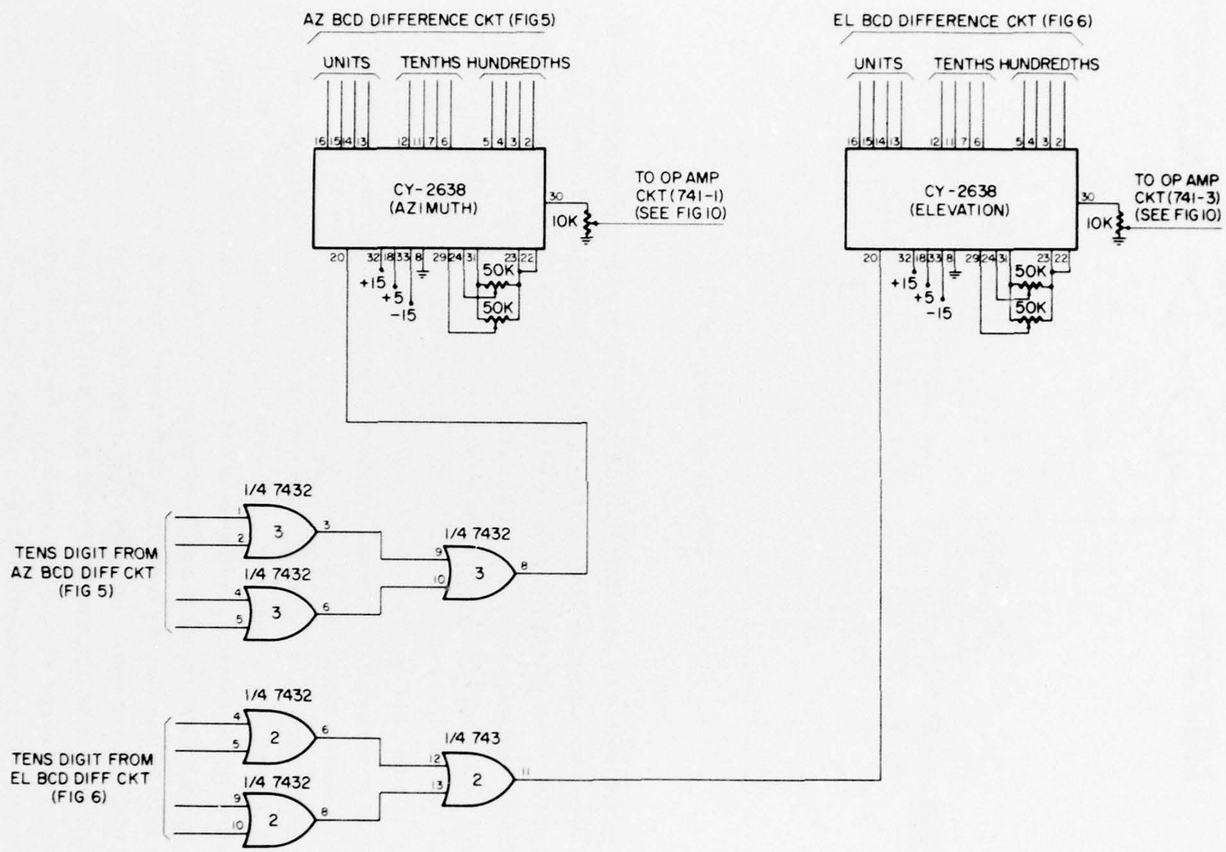

Figure 9. Digital to Analog Converter Circuit

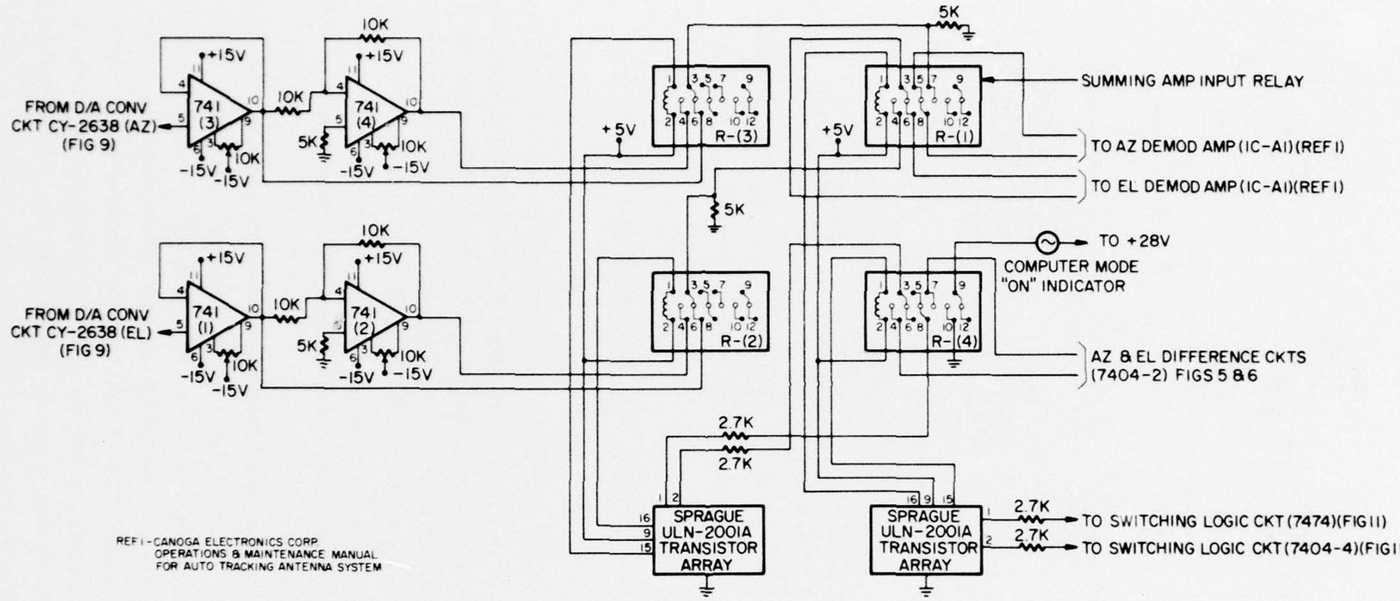

Figure 10. OP-AMP and Relay Circuit

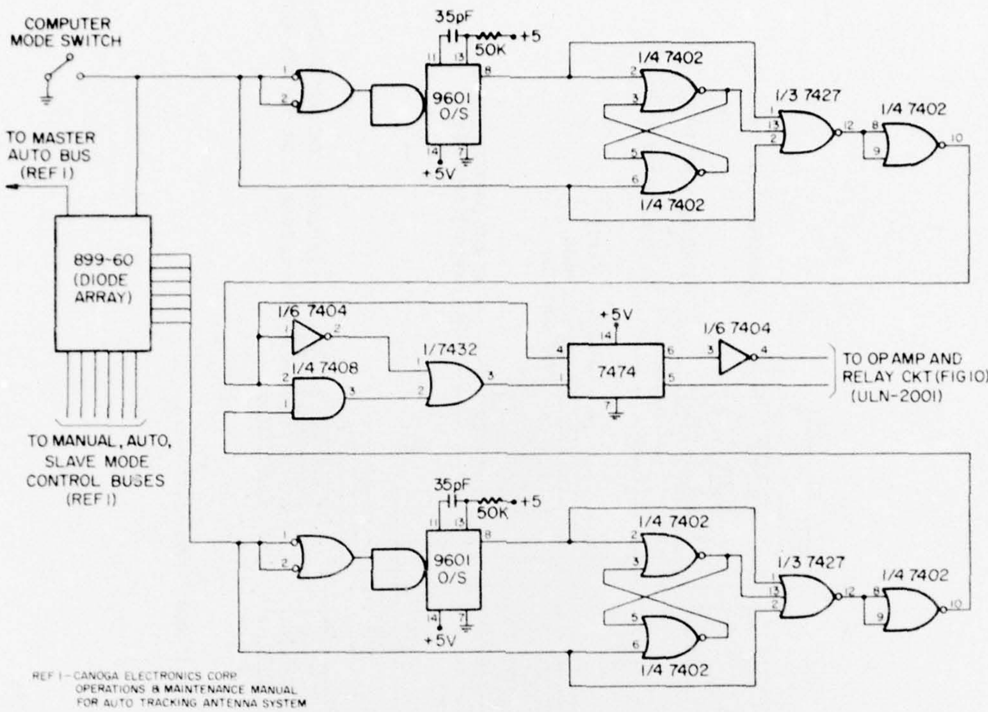

Figure 11. Switching Logic Circuit

A power-up circuit was designed into the system to zero all registers which could initialize with random or unallowed digits upon application of power. This circuit also provides a delayed latching pulse to the BCD difference readouts which would latch the actual position of the antenna at the time of power on (difference between azimuth and elevation actual and zero). Thus the operator has a quick check method of determining whether the difference circuits are operating correctly by comparing the difference reading with the actual encoder readouts. This circuit is shown in Figure 12.

In order to initialize the system for start, an address was allocated to the computer which would sequence the data values for T = 0+ (some time slightly greater than 0) into the interface registers. The data values for the next time increment chosen (time increment is variable) are then placed into the buffer registers thereby initializing the system. The reason for placing data values corresponding to T = 0+ into the interface registers results from the fact that using data for T = 0 during initialization would cause a time comparison to occur which would then start the sequencing of data prematurely.

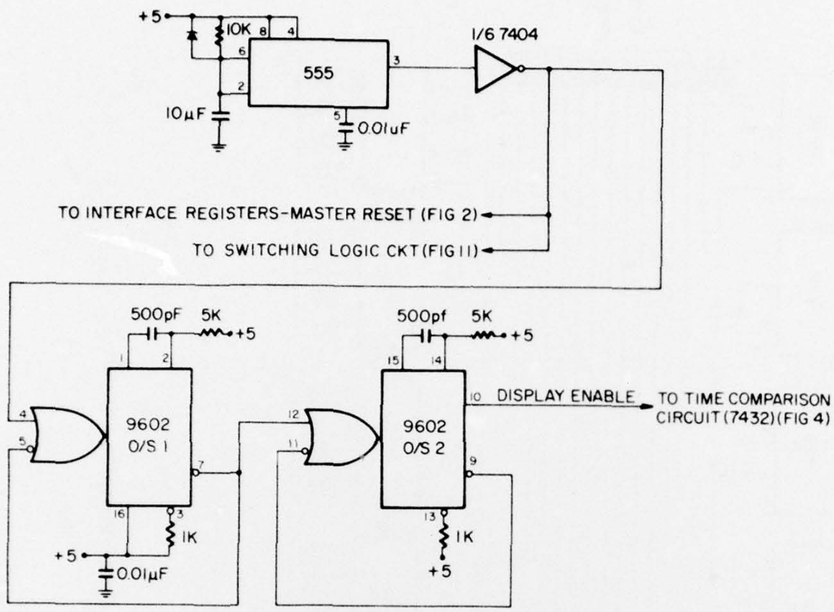

Figure 12. Power Up Circuit

Actual tracking encoder data as well as time and range data are made available to the computer via 16 data multiplexers. With the computer read/write line in the read mode, the 16 data multiplexers are enabled, thus allowing the computer to read the actual data into memory for either flight or post-flight use. The addresses assigned for data read operations are shown in Table 1. In Figure 13 the circuit used for data read operations is shown.

In order to improve system noise immunity between the computer and the interface circuits, drivers and dual terminators were added to interface lines. The circuits utilized for this purpose are shown in Figure 14.

The entire system was built on MUPAC circuit boards using wirewrap techniques. Power requirements for the system are approximately 12 A at +5 V and 100 mA at ± 15 V.

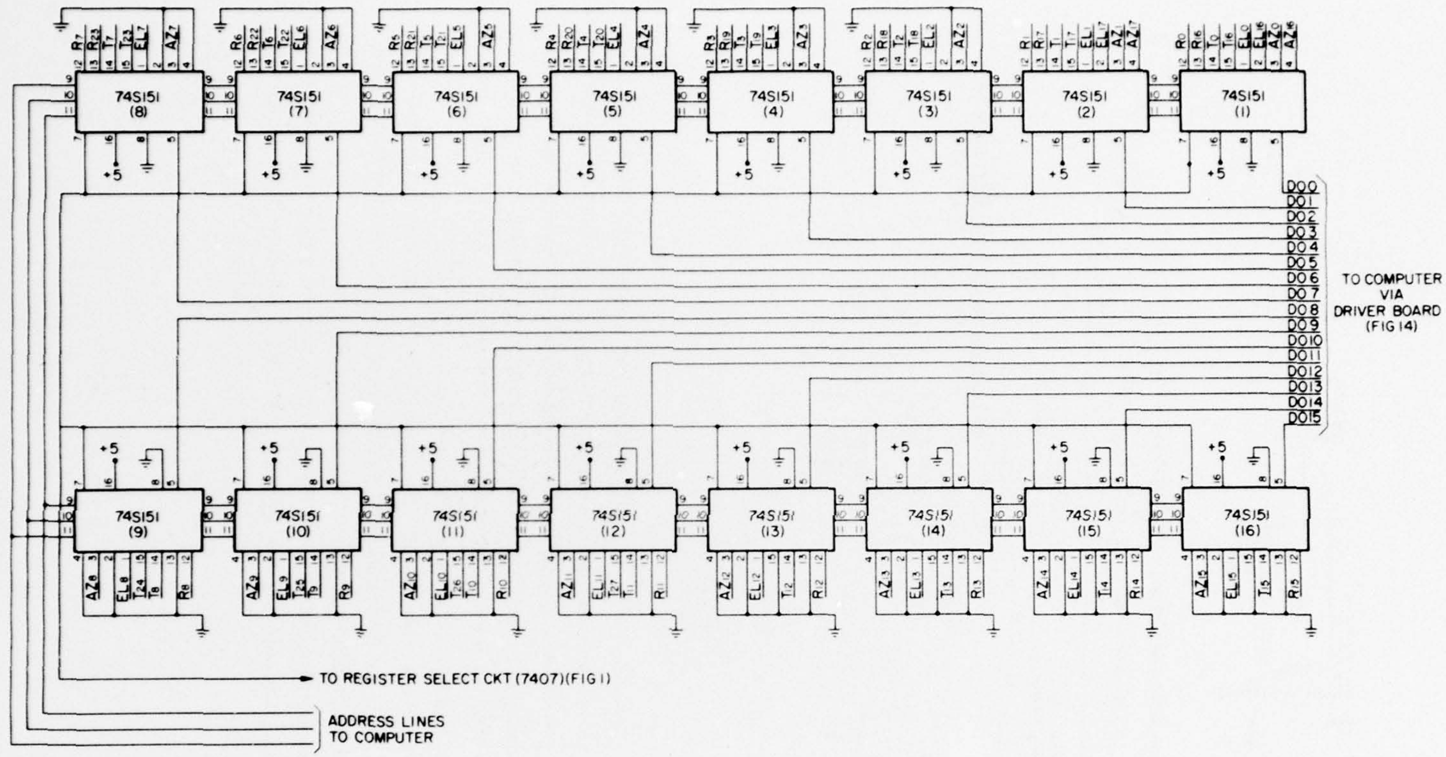

Figure 13. Data Multiplex Circuit

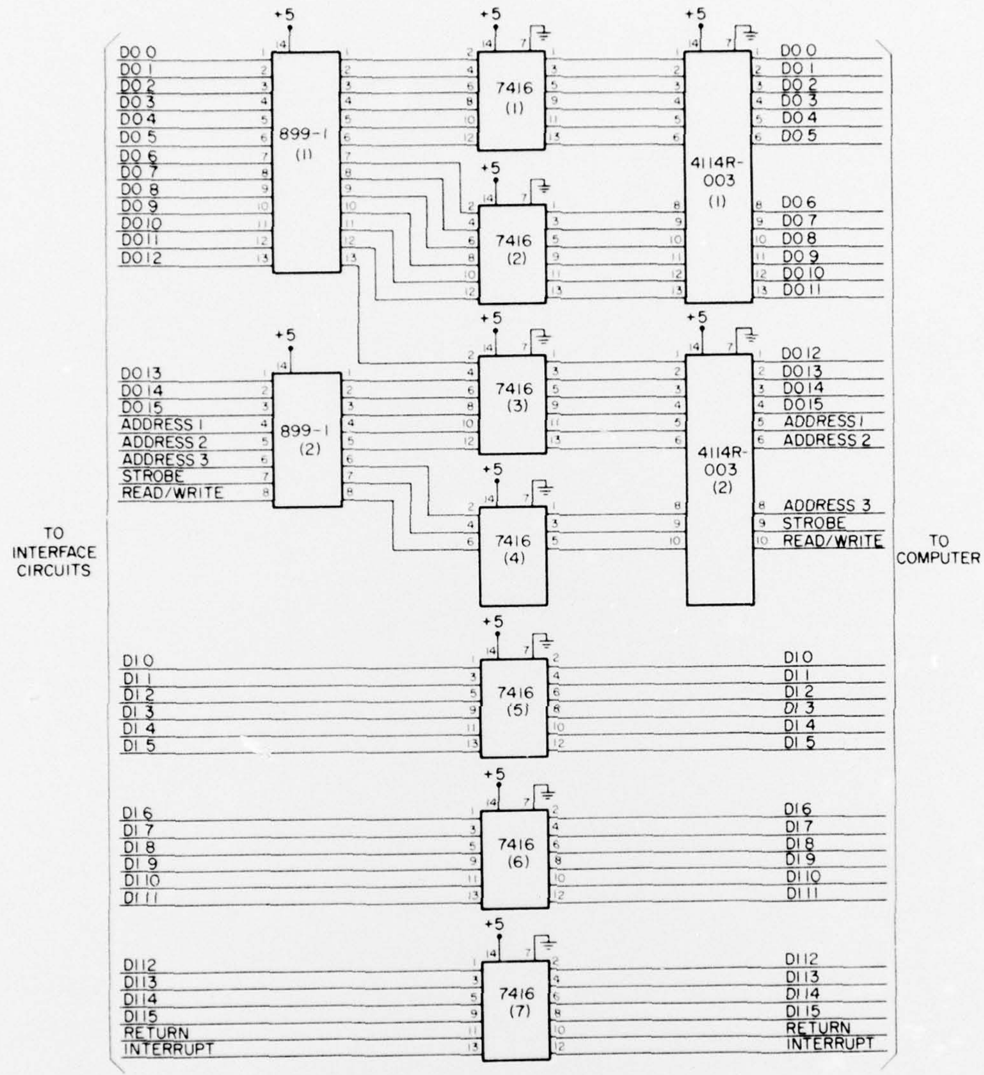

Figure 14. Driver Circuit

4. CONCLUSIONS

A reliable method of interfacing a Lockheed SUE mini-computer with a Canoga Tracking System for the purpose of computer-controlling a ground-based telemetry tracking antenna has been developed to provide increased support to AFSC programs. This effort is but one of many undertaken by the Aerospace Instrumentation Division to maintain its "state-of-the-art" capability in Research Probe Telemetry Systems.

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1. Canoga Electronics Corporation Operations and Maintenance Manual for Automatic Tracking Antenna System (F19650-70-C-0325).
2. Lockheed SUE Computer Handbook.

Abbreviations

1.	BCD	-	Binary Coded Decimal
2.	LOS	-	Loss of Signal
3.	IC	-	Integrated Circuit
4.	OP-AMP	-	Operational Amplifier
5.	LED	-	Light Emitting Diode
6.	D/A	-	Digital to Analog Converter
7.	RF	-	Radio Frequency
8.	IF	-	Intermediate Frequency
9.	MUPAC	-	Microelectronic Packaging Systems and Accessories